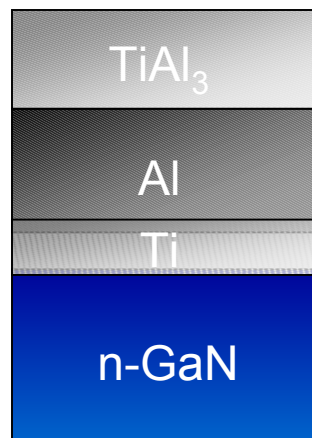
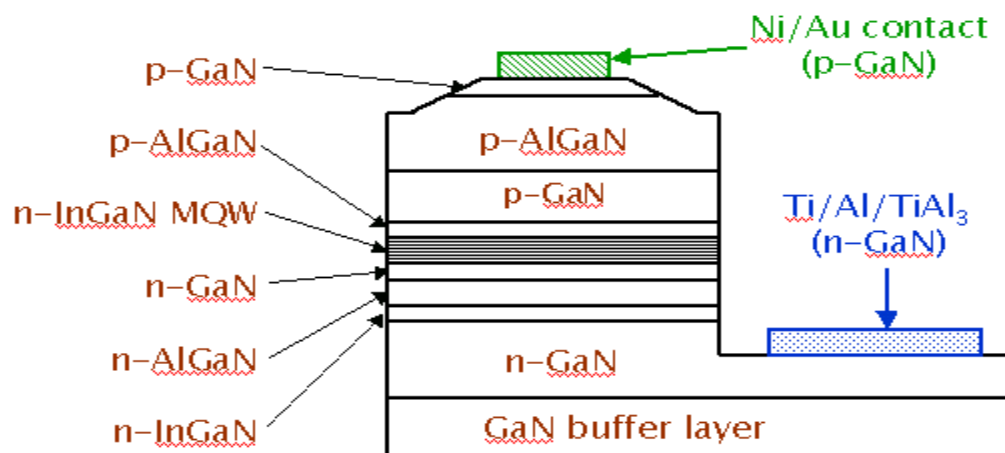


# Thermally stable, oxidation resistant cap for Ti/Al ohmic contacts to n-GaN

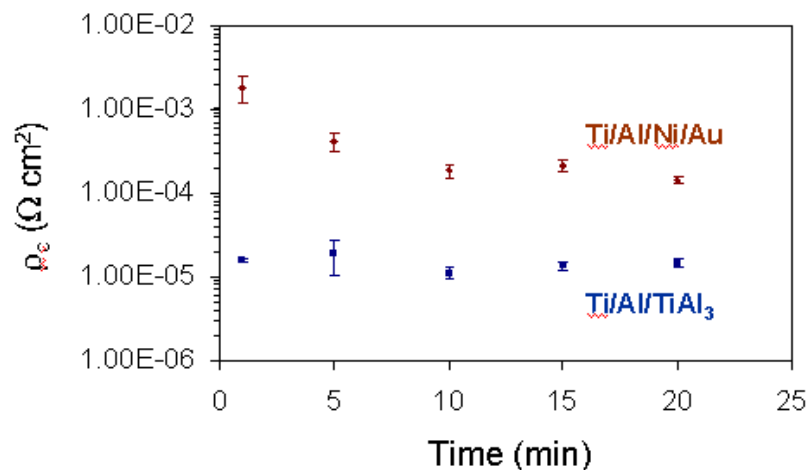


The intermetallic  $\text{TiAl}_3$  is deposited on top of standard  $\text{Ti/Al}$



Devices like laser diodes have p-GaN and n-GaN ohmic contacts on the same device, so parallel optimization is crucial

Contacts annealed in air at  $600^\circ\text{C}$



The  $\text{Ti/Al/TiAl}_3$  contact can achieve near optimal performance when annealed in a very similar environment to the p-GaN ohmic contacts. It can also withstand long anneals in these conditions without degrading.

**Contacts to GaN.** Y. A. Chang and T. F. Kuech; Materials Science Program, University of Wisconsin-Madison. Y. Chen and R. S. Williams; Quantum Science Research, Hewlett-Packard Corporation. Ti/Al bilayer contact structures are at the heart of most successful ohmic, or low resistance contacts to n-GaN. In these structures, the Ti layer is deposited first on the GaN substrate, followed by the deposition of a thicker Al layer (which is usually about three times the thickness of the Ti layer). Both the Ti and Al metal layers are very susceptible to oxidation, though, so additional layers are deposited on top of the structure to allow the bilayer to achieve the lowest contact resistance possible. To date, the most common capping scheme for Ti/Al consists of a Ni/Au bilayer deposited on top, where Ni is deposited on the Al. This cap improves upon the thermal properties of the original Ti/Al, but it requires annealing treatment usually above 900°C for a period no longer than a few seconds to achieve the lowest contact resistance. Since GaN-based light emitting devices, such as laser diodes, require both an n-GaN and p-GaN ohmic, the ability to process both contacts in parallel is a necessity. Unfortunately, the most successful p-GaN contacts usually must be annealed in an oxidizing atmosphere for several minutes at temperatures around 500°C, making it difficult to achieve optimum performance from both the contacts. We employ a TiAl<sub>3</sub> cap for the Ti/Al structure to address this issue. Many researchers have observed that the Ti/Al bilayer transforms to TiAl<sub>3</sub> following thermal treatment for ohmic contact, thus a TiAl<sub>3</sub> cap deposited directly on top of the upper Al layer should be a perfect match for protecting the contact from oxidation during the optimization anneal. The reason for that it is such a good choice is that the TiAl<sub>3</sub> is in thermal equilibrium with the Al so it will not interfere with a previously optimized Ti/Al bilayer recipe, and it is the only Ti-Al intermetallic to form a protective oxide layer. We found that the Ti/Al/TiAl<sub>3</sub> contact achieves a specific contact resistance ( $\rho_c$ ) of  $2.1 \times 10^{-5} \Omega \text{ cm}^2$  following 1 min at 700°C, which compares favorably with a standard Ti/Al/Ni/Au contact's  $\rho_c$  of  $1.8 \times 10^{-5} \Omega \text{ cm}^2$  following a much more extreme anneal at 900°C for 15 s. Both these anneals were performed in an ambient that was specially controlled to minimize oxygen. When annealed at 600°C in air for up to 20 min, the Ti/Al/TiAl<sub>3</sub> contact shows very little sensitivity to the amount of oxygen, and manages to achieve a  $\rho_c$  that is very close to the value following the optimized anneal in the oxygen clean ambient. This result shows that the TiAl<sub>3</sub>-capped Ti/Al contact structure can be employed as an n-GaN contact on devices, and optimized in parallel with the p-GaN contact.